Chapter 7

U.S. MISSILE SYSTEMS

BRIEF HISTORY OF THE ICBM

The first reference to use of rockets dates from 1232 when the Chinese defenders of K'aifung-fu used "fire arrows" against attacking Mongols. Progress in rocketry was slow, at best, for the next seven centuries.

The Germans began development of a missile arsenal during the 1930s at Kummersdorf and Peenemunde, with increased emphasis during World War II. These experiments resulted in the "Vergeltsungswaffe Ein" and "Zwei," (Revenge weapons one and two), or V-1 and V-2. The V-2 was 46 feet long and used alcohol and liquid oxygen as propellants. It reached an altitude of 50 to 60 miles, had a maximum range of 200 miles and carried a one ton warhead. The system's accuracy was two and one-half miles. The war ended before the results of research into longer-range (transatlantic) two-stage rockets called the A-9 and A-10 could be used. These weapons could have been operational in 1948.

The United States and the Soviet Union recruited as many German scientists as possible following the war. Each began their own research programs into the use of missiles as weapons. Funding and weight limitations prevented these programs from quickly advancing. It wasn't until 1954 that Air Force Secretary Talbott directed all necessary steps be taken to advance the Atlas Intercontinental Ballistic Missile (ICBM) project.

On 27 October 1955, a contract was awarded to produce another ICBM, the Titan I. The Thor and Jupiter Intermediate Range Ballistic Missile (IRBM) programs also began in December of 1955, with the highest possible priority. The Army had responsibility for all short-range (under 200 miles) surface-to-surface missiles. The Navy had control of all ship-based missiles and the Air Force got all other surface-to-surface missiles.

The first U.S. IRBM was the Thor (**Fig. 7-1**). It was deployed in the United Kingdom between 1959 and 1963. The Thor was housed horizontally in an above-ground shelter. It had to be raised to the vertical position and fueled before launch. Its propellants were RP-1 (a high grade kerosene) and liquid oxygen. The Thor had a range of 1,500 nautical miles (NM) and could place a one megaton warhead within 4,600 feet of the target.

Fig. 7-1. Thor and Atlas I Missiles

The first Atlas D ICBM was delivered to Vandenberg AFB, California in February 1959 and launched 9 September 1959. General Thomas D. Power, CINCSAC, then declared the Atlas operational. Only six days later, a Minuteman R & D tethered launch occurred at Edwards AFB, California. This was a model with inert second and third stages and a partially charged first stage. It had a 2,000 foot nylon tether to keep the missile from going too far. On 31 October 59, the first nuclear-tipped Atlas was on alert at launcher 576A-1 at Vandenberg AFB. Deployment of the Atlas continued in three versions, the D, E and F models. The D model was housed horizontally in an above-ground, soft building and erected for launch (three D models were in soft, vertical gantries at Vandenberg AFB). It used a combination of both radio and inertial guidance.

The E model incorporated many improvements over the D model. Perhaps the most significant was the replacement of radio guidance with an all-inertial system, making the E model invulnerable to jamming. The E model was also housed horizontally, but it was in a semi-hard coffin launcher that was buried to reduce its vulnerability to blast and overpressure.

The F model was kept in an underground, hardened silo and raised to the surface by an elevator for launch; this was called "hard silo-lift." The silo was nearly 180 feet deep.

The Titan I was also being developed and deployed in a similar configuration as the Atlas F. Both used the same propellants and the same silo lift technique. One primary difference was in the command and control. The Atlas F system had one launch control center connected with, and in command of, one silo with its attendant missile. The Titan I system connected three silos to the underground launch control center. Another difference was that the Titan I used a radio-inertial guidance system similar to the Atlas D. The sixth and last Titan I squadron became operational at Mountain Home AFB, Idaho on 16 August 1962. Only four months later, on 20 December, the last Atlas F squadron at Plattsburgh AFB, New York achieved operational status.

Even as these milestones were reached, the days of this first generation ICBMs were numbered. The newer Titan II and Minuteman ICBMs were more survivable and quicker reacting, along with being more economical to operate and more reliable. On 24 May 1963, General Curtis E. LeMay, Air Force Chief of Staff, announced the phaseout of the Atlas D and E and the Titan I. By its completion, that phaseout also encompassed the Atlas F, with the last Atlas F being removed from alert at Lincoln AFB, Nebraska on 12 April 1965 and shipped to Norton AFB, California for storage.

The second generation of ICBMs, the Titan II and the Minuteman, shared only one characteristic--they were housed and launched from hardened underground silos. The Titan II was a large, two-stage liquid-fueled missile that carried a single warhead. Its range was about 5,500 NM. The missiles were deployed at three wings. Davis-Monthan AFB, Arizona was the home of the first operational wing.

The Titan II offered five distinct advantages over the Titan I. First, its reaction time was reduced from 15 minutes to less than one minute because it used storable hypergolic propellants. Second, it used an all-inertial guidance system, a major improvement over its radio-controlled predecessor. Third, the missile carried the largest and most powerful warhead ever placed on a U.S. missile. Fourth, each launch complex contained only one missile, instead of the cluster of three used in Titan I. This separation enhanced survivability. And last, the Titan II was designed to be launched from below ground inside its silo, also to limit its vulnerability to damage, except during the earliest stages of flight.

The Minuteman is a three-stage, solid-fueled missile housed in a remote launch facility. Its range is also in excess of 5,500 NM. From the beginning, it was intended to be a simple, efficient and survivable weapon system. Its main features are reliability and quick reaction.

The first Minuteman, the Minuteman I "A," went on strategic alert during the

Cuban missile crisis of October 1962. President Kennedy later referred to this missile as his "ace in the hole" during negotiations with the Soviets.

The Minuteman II became operational in 1964 and replaced many of the Minuteman I's. This system, known as the LGM30F, or more simply the "F" model, was over 57 feet long, weighed over 73,000 pounds and carried one warhead, like the Minuteman I.

The Titan crew consisted of two officers and two enlisted technicians, where the Minuteman crew is composed of only two officers. Control of a single Titan missile was done from the Launch Control Center (LCC). Minuteman uses a similar procedure, but the crew controls 10 to 50 missiles.

While Titan II missiles were deployed in only one model, the Minuteman series spanned several models. The latest, and only operational version, is the Minuteman III "G." The last Minuteman III was deployed in July 1975.

1984. The last Titan II wing was deactivated in August 1987. The Bush Administration began deactivation of the Minuteman II to comply with Strategic Arms Reduction Treaty (START) requirements. By 2003, only single-warhead Minuteman IIIs will be operational as ICBMs.

As noted earlier, the oldest ICBM on alert is the Minuteman III "G." It is almost 60 feet tall and weighs approximately 78,000 pounds. The Minuteman III can carry three reentry vehicles, each capable of striking a different target. The Minuteman is hot-launched (ignition occurs in the silo) and flies out through its own flame and exhaust. An avcoat material protects the first stage from the extreme heat generated during this process. Once ignition occurs, the missile will pass through several phases of flight, beginning with the boost phase. A typical flight profile is shown in **Figure 7-2**.

The newest U.S. ICBM is the Peacekeeper. It is a four-stage, solid-fuel

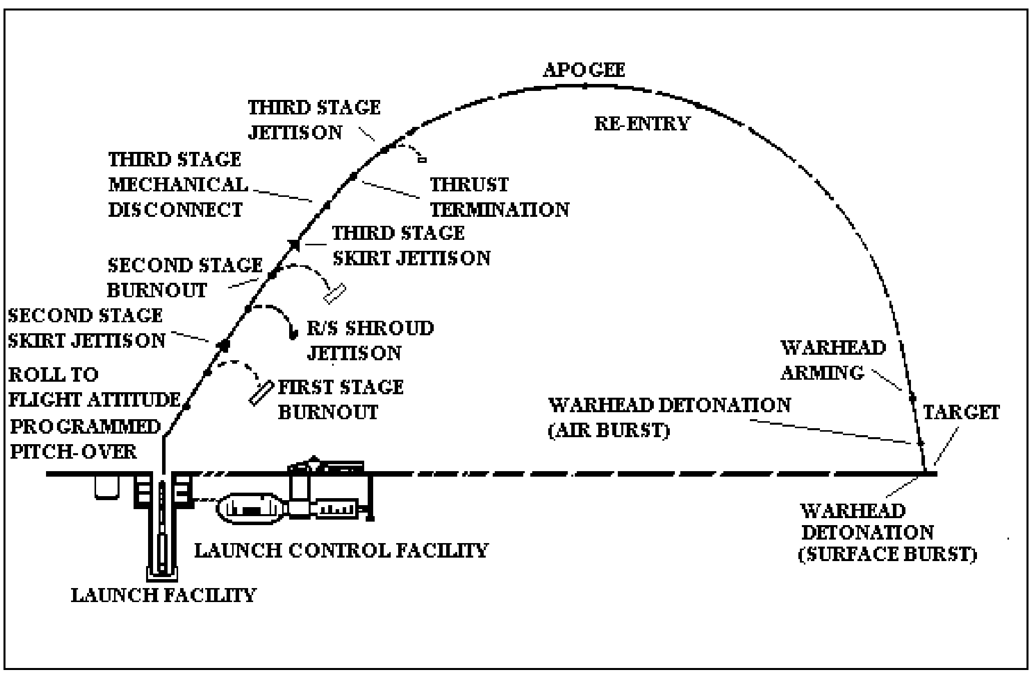

Fig. 7-2. Typical ICBM Flight Profile

Increasingly expensive to operate and hampered by a series of accidents, the Reagan Administration announced the deactivation of the Titan system in October 1982. The deactivation began in

missile which replaced 50 Minuteman III missiles at F.E. Warren AFB, Wyoming. These missiles are deployed in converted Minuteman silos. The first ten Peacekeeper missiles achieved operational alert status in

December 1986 as part of the 400th Strategic Missile Squadron.

The Peacekeeper is 71 feet long and weighs 198,000 pounds--nearly three times the weight of a Minuteman III. This allows it to carry up to 12 reentry vehicles. The missile is about seven and one-half feet in diameter on all of its stages.

All four stages are protected during launch and in its flight environment by an ethylene-acrylic rubber coating. No ablative material is needed because it uses a cold-launch technique similar to the system used by the Submarine Launched Ballistic Missile (SLBM) submarines. The Peacekeeper is protected inside the canister by Teflon-coated urethane pads. Nine rows of pads are used to protect and guide the missile smoothly up and out of the canister. The pads fall away when exiting the canister.

The cold launch system uses a reinforced steel canister to house the missile. At the bottom of the canister is a Launch Ejection Gas Generator (LEGG). A small rocket motor is fired into 130 gallons of water contained in the LEGG reservoir. This creates steam pressure that pushes the Peacekeeper up and out of the canister prior to first stage ignition.

The presently deployed ICBM force consists of Minuteman III "G" and Peacekeeper missiles. They are deployed as follows:

- 200 Minuteman III, Malmstrom AFB, Montana
- 150 Minuteman III, Minot AFB, North Dakota, and
- 150 Minuteman III/50 Peacekeeper, F.E. Warren AFB, Wyoming.

ICBM Characteristics

Mission Profile and Equipment

The ballistic missile as a weapon is often compared to an artillery cannon and its ballistic projectile. Important to the accuracy of the artillery projectile are its elevation and speed. Apart from atmospheric resistance, gravity is the only vital force operating on the projectile, causing a constant acceleration fall to earth. As the distance to the target increases, so must the elevation (height above the target) or speed (muzzle velocity) of the projectile increase.

In order for the ballistic missile reentry vehicle (RV) to reach the target, the missile must be aimed toward the desired impact point and given a specific speed and altitude. There is one point somewhere along the missile flight path at which a definite speed must be achieved. The flight control system is responsible for getting the missile to this point.

From the moment of lift-off, the missile must stabilize in its vertical climb. It must be rolled about its longitudinal axis to the target azimuth and pitched over toward the target. The missile must be accelerated, staged and given any necessary corrections along its roll, pitch and yaw axes, and various engines must be ignited and terminated at precise times. In addition, the reentry vehicle must be armed and separated from the missile. These operations are performed by the flight control system through two basic subsystems; (1) the autopilot subsystem (or attitude control) and (2), the inertial guidance subsystem or radio.

Missiles equipped for radio-inertial guidance, such as some space launch vehicles (SLVs) from Vandenberg, must have two-way communications with a ground station. The ground station continuously monitors the position and speed of the missile during the powered portion of the flight using radio communications. As with virtually any radio communications, the signal is subject to jamming and interference. Either or both of these actions could be detrimental to the missile's powered flight performance.

An inertial guidance system is completely independent of ground control. It is capable of measuring its position in space, computing a trajectory taking the payload to the target. It generates; (1) steering signals to properly orient the missile, (2) engine cutoff signals and (3), the warhead prearming signals.

The tactical advantages of this system compared to the radio-guided system are:

- Relative immunity from jamming
- Less likelihood of detection (no signals transmitted to/from the missile)
- Independence in flight (destruction of ground facilities after launch has no effect on the missile's mission)
- Allows greater dispersal of individual launchers

The Reentry Vehicle

Many do not understand what is meant by "ballistic missile." The total flight time for an ICBM is about 30 minutes. During this time it is actually in powered flight for only five to 10 minutes. The remainder of the time is spent "coasting" to the target. The velocity of powered flight may reach 15,000 mph, but it really is gravity that does the work of getting the payload to the target. Once the vehicle begins to encounter atmospheric drag during reentry, aerodynamic heating and braking begins. Induced drag and lift affect the reentry vehicle's trajectory. There are no control surfaces on a true ballistic reentry vehicle. It acts more like a bullet as it falls to the target.

The development of reentry vehicles may be divided into two phases; heat sink vehicles and ablative vehicles. Heat sink vehicles disperse heat through a large volume of metal, while ablative vehicles have coverings that melt or burn off. Essentially, the covering absorbs the heat and sloughs off, carrying away the heat.

Reentry is incredibly severe with an interesting tradeoff between survivability and accuracy. In general, the steeper the reentry angle, the more accurate the ballistic vehicle. However, the steeper the angle, the higher the temperature and G-loading encountered. The problem is to design a reentry vehicle that will not vaporize when reentering the earth's atmosphere and yet maintain the needed accuracy. An intense program covering shock tests, materials research, hypersonic wind tunnel tests, ballistic research, nose cone drop tests and hypersonic flight was used during development.

There are several design requirements for an RV. Foremost is the ability to survive the heat encountered during reentry. A body reentering the atmosphere at speeds approaching Mach 20 experience temperatures in excess of 15,000 degrees Fahrenheit. In practice, the RV never reaches this temperature because of a strong shock wave ahead of the blunt body that dissipates more than 90 percent of this energy to the atmosphere. In addition, the internal temperature must be kept low enough to allow the warhead to survive reentry. As the RV reenters the atmosphere, it encounters tremendous deceleration forces--as high as 50 Gs. All internal operational components must function under these extreme conditions and additionally, must withstand the high lateral loads and intense vibrations also encountered.

A RV may be deflected from its calculated trajectory by aerodynamic lift forces. Stability, assisted by a form of attitude control and further augmented by some means of averaging deflection, must be designed into the RV. An arming and fusing mechanism must be incorporated into the RV to prevent non-programmed weapon detonation. It also must have a sensing mechanism to indicate the proximity of the target and arm the warhead. The weight of the vehicle must be kept to a minimum to maximize range. The higher the terminal velocity, the less likely the RV will be intercepted. It also decreases the probability of missing the target due to atmospheric deflection.

The primary purpose of the RV is to provide thermal protection for the payload. Internal components must be maintained at a relatively low temperature, making insulation vital. Heat is transferred to the vehicle through a variety of ways, including convection, friction, and radiation. Heat sink vehicles have inherent limitations because of the low heat capacities of metals and the high weights. Beryllium is the most useful metal for heat sink RVs. Copper was also widely used. As missile performance improved, the poor characteristics of the heat sink RV necessitated a change in technology.

Continued use of heat sink vehicles became impractical because of the trade-off between RV weight, booster size and range. The use of ablative vehicles reduced these problems. During the search for better nozzle and jet vane materials for the Hermes' project in the early 1950s, glass fiber reinforced plastics were investigated. Although these materials eroded badly, portions still remained, giving rise to further research.

The ballistic reentry program and its high temperature problems again brought thermal protection to the foreground. Research program led to the development of ablative materials for hypersonic flight. General Electric, under Air Force contract, led the way. Models were tested in a rocket motor exhaust to simulate velocities up to 13,000 feet per second. These tests determined the hypersonic ablative characteristics of reinforced plastics. In 1957, General Electric built a data capsule as the first production vehicle made from ablative materials. More research continued as part of the Jupiter program.

As a result of these tests, ablative materials have been developed in the following categories:

- Pure plastics
- Plastics reinforced with organic or inorganic fibers
- Silica or other oxides
- Carbon or graphite
- Teflon

Most ablative surfaces employed today use one or a combination of the above types.

Nuclear Weapons Effects

Nuclear weapons effects are normally divided into three areas; initial, residual and long-lived. Residual effects are those which begin about one minute after the detonation and continue for about two weeks. These would include fallout and associated radiation. Long-lived effects would include the subsequent damage to the environment and some radiation concerns. It is generally the initial effects that are most germane to military matters. There are six primary nuclear weapon effects. These are:

- Electromagnetic Pulse (EMP)
- Nuclear radiation
- Air blast
- Ground shock
- Thermal radiation
- Dust and debris.

Each of these effects can be compared to our normal phenomena. Electromagnetic pulse is similar to a lightning bolt, producing a tremendous surge of electrical current and generating huge magnetic fields--either or both of which effects electrical equipment. Depending on the altitude of the explosion, it can have effects thousands of miles from the detonation. Nuclear radiation is similar to a powerful X-ray and varies depending on the burst option used (**Fig. 7-3**).

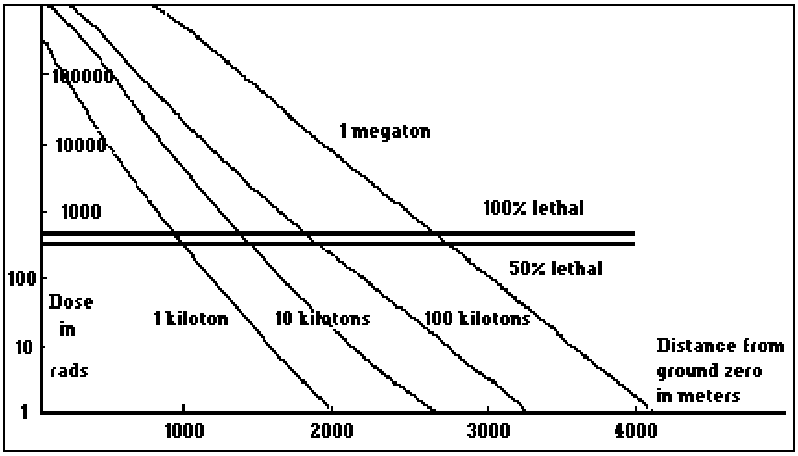

Fig. 7-3. Nuclear Weapon Effects versus Distance

Air blast is the wind generated by the detonation. These winds are ten times stronger than those found in the most powerful hurricane. They actually "slap" the earth hard enough to contribute to the ground shock at the detonation site. The ground shock is nearly 250 times worse than the greatest earthquake. The lateral accelerations are transmitted over large distances at very high speeds. Heat is another product, with the sun's thermal radiation a useful comparison. The temperatures in the fireball reach upwards of 14,000 degrees Fahrenheit. As a comparison, the sun's surface temperature is approximately 11,000 degrees.

Finally, a ground burst will generate large amounts of dust and debris. The debris can bury undamaged structures while the dust clouds can act as sandblasting equipment on aircraft and missiles flying through them.

The most familiar phenomena relating to both blast effects and target hardness is overpressure. This is measured in pounds per square inch (psi). A one cubic foot block of concrete exerts one psi on the ground beneath.

Stacking a second block on the first will increase the pressure to two psi, etc. Five Washington Monuments placed atop each other equates to 500 psi; a sonic boom registers a mere 0.3 psi.

Blast overpressure is heightened by the interaction of the primary shock wave and a reflected shock wave. The primary wave is radiated outward from ground zero and compresses the air in front of it. This wave will strike the earth and reflect upward and outward, creating the reflected wave. This reflected wave moves faster than the primary wave because the air resistance has been decreased by the passage of the first wave. The primary wave will be reinforced by the reflected wave, forming a "mach front." A drawing of this phenomenon would resemble the letter "Y" with the intersection of the "Y" termed the "Triple Point." Below the triple point, the two blast waves will strike like a single, powerful blow. Anything above the triple point is the overpressure.

Table 7-1 depicts some structural failure modes based on psi overpressures.

The power of a nuclear explosion is almost incomprehensible, but the following example may help to put it into perspective. Five million one-ton pickup trucks loaded with TNT would have the same explosive yield as a single *five megaton* nuclear weapon. A surface burst of this weapon will yield the following results at a distance 3,200 feet (0.6 miles) from ground zero:

- Fireball diameter: 2.8 miles
- 5.5 billion kW hours X-rays
- 14,000 degrees
- 250 G lateral acceleration
- 500 psi
- 3,500 mph winds
- 20 inches of debris
- Debris weighing as much as 2,000 lbs. impacting at 250 mph
- Crater: 3,000 ft wide; 700 ft deep

The effects on people are shown in **Table 7-2** on the next page.

Table 7-1. Overpressure Sensitivities		
Structural Element	**Failure**	**Approximate Side-on Peak Overpressure (PSI)**
Glass windows, large & small	Shattering, occasional frame failure	0.5 - 1.0
Corrugated asbestos siding	Shattering	1.0 - 2.0
Corrugated steel paneling	Connection failure followed by buckling	1.0 - 2.0
Wood-frame construction	Failure occurs at main connections, allowing a whole panel to be blown in	1.0 - 2.0
Concrete or cinder block wall panels, 8-12 inches thick (unreinforced)	Shattering	1.5 - 5.5
Brick wall panel, 8-12 inches thick (unreinforced)	Shearing and flexure	3.0 - 10.0

Table 7-2. Nuclear Radiation Effects on People			
Dose in Rems	**Radius in feet from 20 KT Air Burst**		**Probable Effects**
	Unprotected Persons	Troops in Covered Foxholes	
0 - 80	5,550	4,200	No obvious effects. Minor blood changes possible.
80 - 120	5,250	3,900	Vomiting and nausea for about one day in 5-10% of exposed persons. Fatigue, but no serious disability.
130 - 170	4,800	3,750	Vomiting and nausea for about one day followed by some symptoms of radiation sickness in about 25% of exposed persons. No deaths anticipated.
180 - 260	4,500	3,600	Vomiting and nausea for about one day followed by some symptoms of radiation sickness in about 50% of exposed persons. No deaths anticipated.
270 - 390	4,200	3,300	Vomiting and nausea in nearly all persons on first day, followed by other symptoms of radiation sickness. About 20% deaths within two to six weeks after exposure. Survivors convalescent for up to three months.
400 - 550	3,900	3,000	The "mid-lethal dose." Vomiting, nausea, and radiation sickness symptoms. About 50% deaths within one month. Survivors convalescent for up to eight months.
550 - 750	3,750	2,850	Vomiting and nausea in all persons within a few hours, followed by other symptoms of radiation sickness. 90% to 100% deaths. The few survivors convalescent for six months.
1,000	3,600	2,550	Vomiting and nausea in all persons exposed. Probably no survivors.
5,000	3,000	2,250	Incapacitation almost immediately. All persons will be fatalities within one week.

U.S. ICBMs

Minuteman III (LGM-30G)

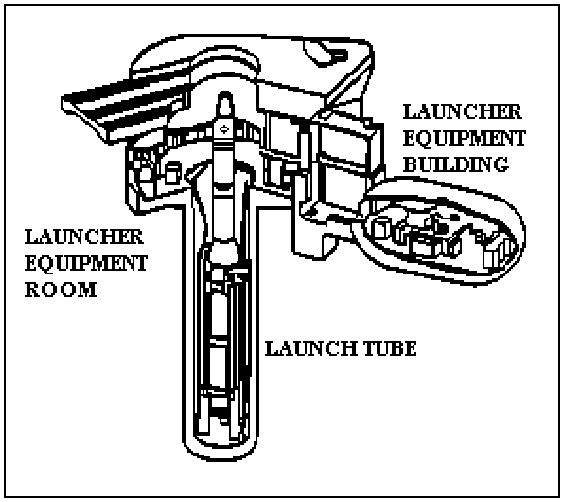

Fig. 7-4. Launch Facility

The Minuteman "G" model is a three-stage, solid-propellant, inertially guided, Intercontinental Ballistic Missile with a range of more than 6,300 miles. It employs a Multiple Independently Targetable Reentry Vehicle (MIRV) system with a maximum of three reentry vehicles. The Post Boost Control System (PBCS) provides maneuvering capability for deployment of the reentry vehicles and penetration aids. It is comprised of a Missile Guidance Set (MGS) and a Propulsion System Rocket Engine (PSRE). The "G" model is maintained on alert in a hardened, underground, unmanned Launch Facility (LF) as depicted in **Figure 7-4**, identical to the "F" model. The LFs are at least three miles apart and three miles from the LCC. Each facility in the squadron is connected to other squadron resources by a buried cable system. This allows one LCC to monitor, command and launch its ten "parent" missiles (flight) and all fifty missiles in the squadron.

Enhancements and modifications are in progress to maintain the viability of the force at least until the year 2010. On the missile itself, the second-stage motors are being washed out and repoured. The third stage motors are being remanufactured. A major effort is under way to test an environmentally acceptable propellant replacement. The Rapid Execution and Combat Targeting (REACT) Program is designed to provide long-term supportability of the aging electronics components. It also modifies the launch control center allowing real-time status information on the weapons and communications nets to correct operability problems, improve responsiveness to launch directives, and provide rapid retargeting capability.

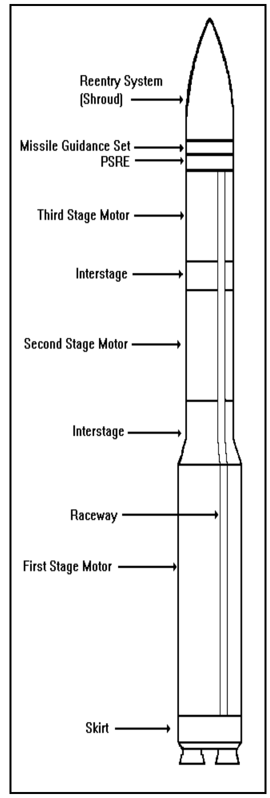

Fig. 7-5. Minuteman III

Propulsion System. Three solid propellant rocket motors make up the propulsion system of the Minuteman "G" model missile (**Fig. 7-5**). The first stage uses a Thiokol M-55 solid-propellant motor that generates 210,000 pounds of thrust. The second stage motor is built by Aerojet (SR19-AJ-1), developing 60,300 pounds of thrust. These stages are identical to the Minuteman "F" model. The third stage is larger than the "F" model and it uses a single, fixed exhaust nozzle with the Liquid Injection Thrust Vector Control (LITVC) system and roll control ports for attitude control. The third stage is a Thiokol SR73-AJ-1 motor that delivers 34,400 pounds of thrust (the third stage on the Minuteman II also uses this motor, but it only generates 17,000 pounds of thrust). Thrust termination is similar to the "F" model but there are six thrust termination ports mounted at the forward end of the third stage. These "blow out" when the desired point in space is reached to employ all weapons. The actual deployment of the reentry vehicles and penetration aids is accomplished by a "mini fourth stage," the PBCS. It fires a liquid-fueled engine periodically to maneuver throughout the deployment sequence. This process allows the "G" model to hit up to three separate targets at different ranges with great accuracy.

Airframe. The missile consists of rocket motors, interstages, a raceway assembly and the Mark 12 reentry system. The reentry system includes a payload mounting platform, penetration aids, reentry vehicles and an aerodynamic shroud. A shroud protects the reentry vehicles during the early phases of powered flight. All three stages of the "G" model are delivered preloaded from the manufacturers and emplaced into the LF as one unit. The PBCS and the reentry system are assembled on the missile in the launch tube after missile emplacement.

Peacekeeper (LGM 118A)

The Peacekeeper is a four-stage, inertially guided, Intercontinental Ballistic Missile with a range of more than 6,000 miles. The first three stages are solid propellant with Kevlar 49 casings. The fourth stage is liquid propelled. The Peacekeeper can carry eleven Mark 21 or twelve Mark 12A reentry vehicles. The operational deployment is ten Mark 21s. The guidance and control system is in stage four and uses a raceway with fiberoptic cabling to transmit commands to the first three stages. Peacekeeper missiles are maintained on alert in modified Minuteman LFs (**Fig. 7-6**) and commanded by modified Minuteman LCCs. Only one squadron of Peacekeeper missiles is operational and it is deployed at F.E. Warren AFB, Wyoming.

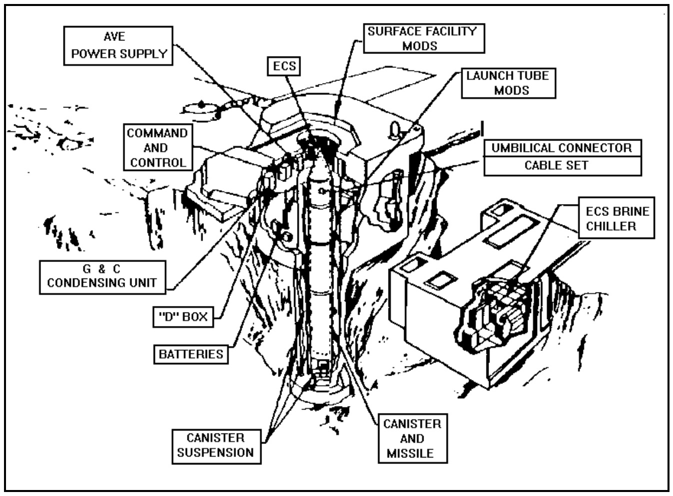

Fig. 7-6. Peacekeeper Launch Facility

Propulsion System. Unlike the Minuteman, Peacekeeper's engines do not ignite in the silo. The missile is in a canister with a Launch Ejection Gas Generator (LEGG). Like a sea-launched ballistic missile, the Peacekeeper is ejected from the canister and propelled some 80 feet into the air before the first stage engine ignites. Peacekeeper's first three stages are solid propellant with single exhaust nozzles. The first stage nozzle is movable through hydraulic actuators powered by a hot gas generator and turbine centrifugal pump. A similar gas generator turbine assembly extends the nozzles on stages two and three. These Extendable Nozzle Exit Cones (ENEC) are folded before stage ignition and extend to provide better performance characteristics without increasing stage diameter or length. The fourth stage, deployment module, guidance and control section and shroud make up the Post Boost Vehicle (PBV). The system operates like the PBCS on the Minuteman "G" model using the new Advanced Inertial Reference Sphere (AIRS) and the Missile Electronics and Computer Assembly (MECA).

Airframe. The missile consists of rocket motors, interstages, a raceway assembly, and the reentry system. The reentry system is the Post Boost Vehicle minus the fourth stage. Peacekeeper is assembled in its canister at the LF following delivery of the components from the manufacturer. Along with several special vehicles, an "air elevator" is used in this assembly process to lower the missile one stage at a time into the canister. This isn't an easy task. It's been described as "similar to stacking BBs."

U.S. SLBMs

SLBM History

In 1955, the National Security Council requested an IRBM for the defense of the U.S. They further decided that part of the IRBM force should be sea-based. As a result, the Navy was directed to design a sea-based support system for the existing liquid-fueled Jupiter IRBM. This led to the development of the Special Projects Office (SPO) by the Secretary of the Navy. The SPO was tasked with adapting the Jupiter IRBM for shipboard launch. Originally, the Jupiter was an Army missile designed for land-based launches. Because of the unique handling and storage requirements of liquid propellants, Navy crews encountered storage and safety problems. As a result, the Navy began a parallel effort to the Air Force in the development of alternate solid-fueled rocket motors.

Breakthroughs in solid fuels, which resulted in smaller and more powerful motors, occurred in 1956. Reductions in the size of missile guidance, reentry vehicles and warheads further aided in smaller missile technology. The first solid-fueled missile incorporating this new technology was named Polaris. The first submarine launch of a Polaris occurred in July 1960 from the USS GEORGE WASHINGTON. Three hours later a second missile was successfully launched. These two shots marked the beginning of sea-based nuclear deterrence for the U.S.

Since then, the Fleet Ballistic Missile (FBM) has progressed through Polaris and Poseidon, to the Trident I and Trident II missiles of today. The Poseidon added MIRV capability while both generations of Trident increased range and accuracy.

There are other changes as well. The launcher system evolved from compressed air units to steam-gas generators. The missile guidance systems now use in-flight stellar updates. Navigation has matured from external fixes to on-board computers. The missile fire control system has developed through semiconductor and solid-state electronics to the present microchip technology.

The first SSBN was constructed by cutting a fast-attack submarine (USS SCORPION) into two pieces and inserting a 16 tube missile compartment section. Since then, several classes of submarines have been designed and built specifically for the FBM mission. The Ohio (726)-class submarine is the newest generation of SSBN. The first submarine of this class was deployed in 1981. This is the same class of submarines that carry the Trident II strategic weapon system (SWS) and missile. Currently, the United States has two different strategic weapon systems (Trident I and Trident II).

<u>Polaris</u>. The Polaris program began in 1957. Among its innovations, the Polaris had a two-stage solid propulsion system, an inertial navigation guidance system and a miniaturized nuclear warhead. Production ended in 1968 after more than 1,400 missiles had been built. The last version, the A-3, had an increased range (2,900 miles compared with 1,700 miles for the A-2 model) and multiple warhead capability. The missile was replaced by the Poseidon SLBM and later by the Trident.

<u>Poseidon</u>. The Poseidon weapon system was deployed on Poseidon (Lafayette-class) submarines. The Poseidon submarine was similar to the submarine that carried the Polaris weapon system. They carried 16 missiles. Poseidon submarines, now out of service (except for two converted to SSNs) were deployed from Charleston, South Carolina and Holy Loch, Scotland.

<u>Trident I</u>. The Trident I backfit weapon system was deployed on Poseidon

submarines. The Trident I backfit weapon system consisted of the Trident I missile and updated launch and preparation equipment. The Trident I missile has increased range and accuracy over the Poseidon. The updated weapon system includes many improvements resulting from new technology.

The Trident I is deployed on the early Ohio-class submarines. This weapon system consists of the Trident I missile and new/modified launch and preparation equipment. The modifications to the launch and preparation equipment result largely from improvements in electronics technology. The Ohio-class submarine was designed from the ground up to carry the new weapon system. It is larger, faster and quieter than the Poseidon submarine and carries 24 Trident I missiles.

<u>Trident II</u>. The Trident II is deployed on the later Trident (Ohio-class) submarines. This weapon system consists of Trident II missiles and a combination of new and modified preparation and launch equipment. The Trident II missile is significantly larger than the Trident I missile because of the increased size of the first stage motor. The Trident II uses the latest electronics for improved reliability and maintainability. The launch platform is basically the same submarine that carries the Trident I and are deployed from the East and West coasts of the United States.

Active SLBMs

Trident I C-4

The Trident I C-4 is a three-stage, solid propellant, inertial/stellar-guided, ICBM. It has a range of 6,900 miles with a nominal range of 4,600 miles. It carries a MIRVed system and was deployed on the Lafayette-class (all retired) and currently on the Ohio-class (Trident) submarines.

<u>Propulsion Subsystem</u>. Three solid propellant rocket motors make up the propulsion system of the C-4 missile (See **Fig. 7-7**). Each stage of the missile contains a nitroglycerin and nitrocellulose-base propellant encased in a Kevlar/epoxy rocket motor casing. Stage I is 14.75 feet long or about half the missile's length. It is six feet wide and weighs approximately 19,300 pounds. The third stage is ten feet tall, 2.6 feet wide, and weighs 4,200 pounds. Each stage is controlled by a single movable nozzle activated by a gas generator. The PBCS and RV mounting platform surrounds the third stage rocket motor. At a predetermined time, a small rocket located on the top of the third stage fires, backing it away from the PBCS. Now taking on a doughnut appearance, the PBCS fires and proceeds to the RV deployment points.

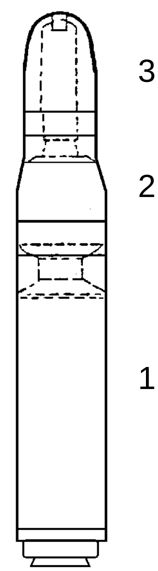

Fig. 7-7. Trident I

<u>Airframe</u>. The airframe of the C-4 is similar to the Poseidon C-3. The C-4 has a length of 34 feet and a diameter of about six feet. An aerodynamic spike (AEROSPIKE) actuates by an inertial pyrotechnic device during first stage flight. This aerospike increases missile range by reducing aerodynamic drag. The nose fairing on the C-4 is also constructed of Sitka Spruce. The fairing jettisons during second stage burn.

Trident II D-5

The Trident II D-5 is a three-stage, solid propellant, inertial/stellar guided, ICBM. It has a range of 6,800 miles with a nominal range of 4,600 miles. It carries a MIRVed re-entry system and is deployed on the Ohio-class submarine.

<u>Propulsion Subsystem</u>. Three solid propellant rocket motors make up the propulsion subsystem of the Trident II D-5 missile (**Fig. 7-8**). Each stage of the D-5, like the C-4, contains nitroglycerin and nitrocellulose-based propellants contained in the motor casing. The motor casing for the first and second stages is constructed of graphite and epoxy, while the third stage of the D-5 consists of Kevlar/epoxy materials. Stage one is approximately eight feet long, almost seven feet wide, and weighs 65,000 pounds. Stage two is eight feet long, seven feet wide and weighs approximately 19,000 lbs. The third stage is 10 feet tall, 2.5 feet in diameter, and weighs 4,200 pounds. A single movable nozzle, actuated by a gas generator, controls each stage. Like the C-4, the third stage of the D-5 is surrounded by the PBCS and the RV mounting platform. During third stage separation, the stage slides back through the equipment section along support rails. Taking on a doughnut appearance, the PBCS fires and proceeds to the deployment points for RV release.

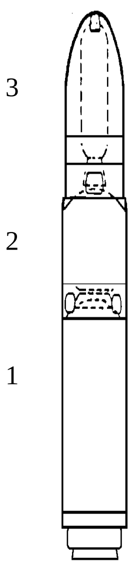

Fig. 7-8. Trident II

<u>Airframe</u>. The Trident II D-5 is 44 feet in length, approximately seven feet in diameter and weighs 130,000 pounds. Like the Trident I C-4, the D-5 employs an AEROSPIKE during first stage burn. The nose fairing is constructed of Sitka Spruce and jettisons during second stage burn. All other airframe characteristics of the D-5 are the same as the Poseidon C-3 and the Trident I C-4.

Ohio Class Submarine

All 18 of a total programmed force of 18 Ohio-class submarines are now operational. As shown in **(Fig. 7-9)**, each is 560 feet long, 42 feet in beam and has a submerged displacement of 18,700 tons. Although over two times larger than the Franklin-class in volume displacement, the Ohio-class requires only 16 officers and 148 enlisted crew members. The Ohio-class submarine carries the Trident I and Trident II missile systems.


Fig. 7-9. Ohio-class Ballistic Missile Submarine

Cruise Missile Weapon Systems

Cruise missile weapon systems consist of the Air Launched Cruise Missile (ALCM) and the Sea Launched Cruise Missile (SLCM) and the Advanced Cruise Missile (ACM). While the launch techniques used by each system are different, their airframe characteristics, guidance systems, propulsion systems and flight profiles are similar.

Airframe

Cruise missile airframes are approximately 20 feet long and 20 inches in diameter. These missiles weigh close to 3,000 pounds at launch. The guidance system in the forward portion of the missile uses two separate techniques to achieve outstanding accuracy. A Terrain Contour Matching (TERCOM) system provides periodic location updates correcting any drift or errors in the inertial guidance set. Aft of the guidance compartment is the warhead. The ALCM and ACM carry nuclear warheads, while the SLCM may be either nuclear or conventional. Behind the warhead is the fuel tank for the turbofan engine. After the fuel tank is the midsection where the missile's wings meet the fuselage.

SLCM and ACM wings are eight feet seven inches long and extend straight out from the fuselage. ALCM wings are 12 feet long and swept back 25 degrees. Aft of the midsection is the air inlet for the turbofan engine. SLCM and ACM air inlets are on the bottom of the airframe while the ALCM's is on top. SLCM and ALCM air inlets are kept retracted into the airframe until needed during flight. Immediately behind the air inlet is the tail cone section which contains an F-107-WR turbofan engine. This engine weighs 145 pounds and produces about 600 pounds of thrust. The tail cone section also provides attachment points for the missile's tail fins. Finally, there is a solid rocket motor on the SLCM. This rocket accelerates the missile to a speed of 550 mph (**Fig. 7-10**).

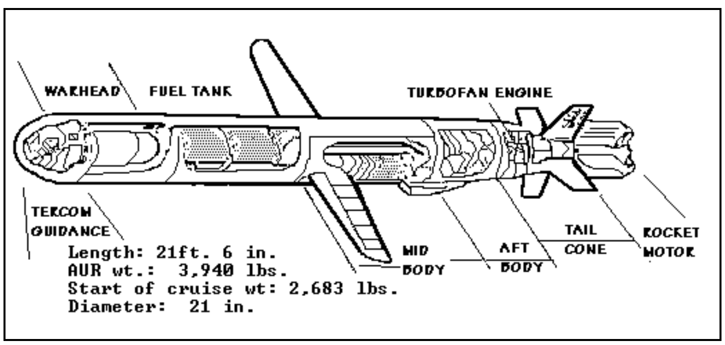

Fig. 7-10. Sea Launched Cruise Missile (SLCM)

ALCM Airframe

The ALCM's overall dimensions and component locations are similar to the SLCM. The ALCM differs from the other cruise missile variants in the shape of its airframe and wings, the location of its air inlet and its lack of a solid rocket motor (shown in **Fig. 7-11**).

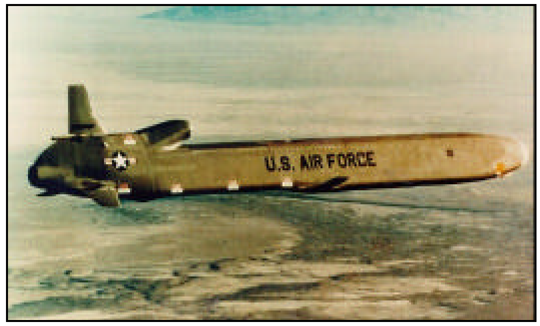

Fig. 7-11. ALCM

Launch

The SLCM comes in a canister, which functions as a shipping and storage container and firing tube. A canister loaded with a warhead-equipped missile is an All-Up-Round (AUR). When a launch command is received, the SLCM's solid rocket motor fires and accelerates the missile to a speed of 550 mph. The tail fins deploy six seconds after the booster ignites. Two seconds later the turbofan sustainer engine starts and propels the missile to its Initial Timing Control Point (ITCP). Since ALCM's initial velocity is provided by its carrier aircraft, it does not need a rocket booster. The ALCM's wings, elevons and fin deploy immediately after the missile is released from the aircraft. The turbofan engine then starts and the flight control system begins. The ALCM then proceeds to the ITCP.

Flight Profile

Flight profiles from the ITCP to the target are similar for both cruise missiles. A pre-programmed path stored in its onboard computer (inertial guidance navigational system) guides the missile from the ITCP to the target. The TERCOM system compares information about the land terrain relief stored in the cruise missile's computer memory with the actual terrain it is flying over. Various altimeters collect the actual terrain relief data. The missile's position is determined and commands are sent to an automatic pilot which corrects the course. Digital maps of terrain areas are compiled by first digitizing the height of a point on the earth's surface whose coordinates are known. Adjoining points are then established assembled into a digitized map of the area and stored in the memory of the cruise missile's computer.

TOC

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